Diseases of CABBAGE and RELATED PLANTS

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CABBAGE DISEASES are preventable in the main by simple means of plant sanitation.

Rotation of crops should be practiced, and crops that belong to the cabbage family, such as cauliflower, turnips, brussels sprouts, and kale, should be avoided in the rotation. Keep down mustard and related weeds, which harbor cabbage pests.

Drainage water, refuse from diseased cabbage fields, and stable manure with which diseased material has been mingled will carry infection.

The seedbed is often the source of infection. The greatest pains should be taken to insure healthy plants. Locate the seedbed on new ground, if possible, or sterilize by steam the soil used.

Soil infested with the clubroot organism should be avoided. Disinfect all cabbage seed before planting, to prevent black rot and blackleg. Yellows is due to a fungus which persists in the soil for many years. Varieties of cabbage resistant to this disease are available.

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DISEASES OF CABBAGE AND RELATED PLANTS

By J. C. WALKER, *agent, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration,* and *professor of plant pathology, University of Wisconsin*

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CABBAGE AND OTHER CRUCIFERS

FROM THE ORIGINAL wild stocks of the cabbage group have come cultivated cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, collards, and kale. Other cultivated plants closely related to those already mentioned are turnip, radish, rape, rutabaga, and horseradish. Among the related wild plants shepherds-purse, pepper-grass, and mustard are of most frequent occurrence. Mustard is sometimes cultivated, but some species grow so profusely under all conditions that they are more commonly classed as obnoxious weeds. The term "crucifers" as used in this bulletin refers collectively to all the vegetables and weeds mentioned in this paragraph, all of which belong to the botanical family Cruciferae, so-called from the form of the four-petaled flower. Many of them are subject to the same diseases, so that the methods of control of the diseases of cabbage and its close relatives can often be applied to other crucifers as well.

PARASITIC AND NONPARASITIC DISEASES

A large number of the diseases discussed in this bulletin are brought about by the plant's being attacked by microscopic organisms—bacteria and fungi—or ultramicroscopic agencies known as viruses. This class of diseases collectively is referred to here as parasitic diseases. Their development is influenced greatly by the climate and by the condition of the soil, as these environmental factors affect not only the aggressiveness of the parasite but also the susceptibility and resistance of the plant it attacks.

There are many disease conditions in which no parasite whatsoever is involved. They result from the detrimental influence of climate and soil upon the crop. This group is referred to as nonparasitic diseases. Outstanding examples of nonparasitic diseases of cabbage are soil-mineral deficiency (for example, potash starvation), flooding injury, and freezing injury.

PARASITIC DISEASES

CONTROL PRACTICES

DISEASE-FREE SEED

Blackleg and black rot are more or less prevalent in all the cabbage sections in the Central, Eastern, and Southern States. The germs of both maladies are readily carried overwinter on even mildly infected seed heads, and they then attack the seed plants the following season. From a diseased field it is almost impossible to select with certainty seed heads that are free from these diseases. The most effective means of ridding seed stock of the diseases, therefore, is to start with clean or thoroughly disinfected seed. By planting clean seed in a clean seedbed and in a clean field, these troublesome diseases may be avoided and clean seed produced.

American cabbage growers, as a rule, prefer to buy seed rather than grow their own. In general this custom is based on sound economic principles and is likely to continue. Seed growing is an industry in itself and requires specialized cultural methods and certain favorable climatic conditions. Because of these facts most of the American supply of cabbage seed is grown near Puget Sound, Wash., or is imported. The cabbage-seed-growing section of Puget Sound appears so far to be free from blackleg and black rot. A study of climatic conditions as affecting these diseases leads to the belief that the dry season in midsummer serves to prevent their development in that section.

If the grower is certain his cabbage seed has been grown in the Puget Sound section it is reasonably safe to proceed without treatment. In all other cases, with other members of the cabbage group (p. 1), and with turnip, rutabaga, and rape, the hot-water seed treatment should be used.

HOT-WATER SEED TREATMENT

Hot-water seed treatment must be applied with great care, since it is likely to reduce germination somewhat. Old seed is more likely to suffer in this respect, and in some cases the length of treatment must be reduced because of this fact. It is well, therefore, to run a preliminary test on a hundred seeds, followed by a germination test, before treating an entire lot. To do this, the seed is placed loosely in a cheesecloth sack. It is then immersed in water held at 122° F. for 15 to 30 minutes, depending upon how long the particular lot will stand being immersed without the rate of germination being greatly reduced. It is essential to keep the water continuously agitated and to maintain the temperature by the frequent addition of hot water without applying it directly to the seed. At the end of the treatment, immerse the seed in cold water, drain, and spread in a thin layer to dry.

SEEDBED SANITATION

Cabbage, cauliflower, and certain other cruciferous crops are generally started in a seedbed. As previously pointed out, the causal organisms of some of the most destructive diseases may be transferred to noninfested fields by means of the plants from the seedbed. The mistake is often made of placing the bed on an old cabbage field where diseases have been present, or often manure is taken from the heap where diseased plants have been thrown to compost or from animals that have fed on diseased root crops. In either case there is great danger of introducing the diseases into the seedbed, because the transfer of such plants to the field naturally means the transfer of the disease germs affecting them. To avoid this danger, the seedbed should always be made on new soil if possible. Where it is necessary to use old soil that may contain germs, it should be disinfected with live steam, as described in Farmers' Bulletin 1629, Steam Sterilization of Soil for Tobacco and Other Crops.

CARE IN PURCHASE OF PLANTS

It is obvious from what has just been said concerning care of the seedbed that extreme caution should be taken in the purchase of plants. It is not always possible to detect diseases, even though present in incipient form at the time of transplanting. The only safe procedure, therefore, is to make sure that proper seed was used and that seedbed sanitation was practiced in growing the plants to be purchased.

CROP ROTATION

Because the germs of certain diseases overwinter in soil and refuse, repeated croppings of the soil with the same plant favor the multiplication of disease organisms. The lack of data as to just how long a time is needed to starve out a given organism, as well as regional variation in climate and soil, makes definite recommendation as to length of rotation difficult. Blackleg and black rot organisms overwinter in the soil in the North to some extent, but a 2- to 3-year rotation seems to be satisfactory. In the case of yellows, when the organism is once established it is so persistent that its reduction by means of rotation is out of the question. Clubroot is also very persistent in the soil. Even long rotation and complete subjection of related wild plants that may harbor the organism are not sure means of ridding the soil of the parasite.

CLUBROOT

Known in Europe for several centuries, clubroot is now worldwide in its occurrence. It probably causes the greatest losses to turnip and rutabaga where these crops are grown extensively for stock feed—as in northern Europe and in New Zealand. In vegetable gardens and in truck-crop districts the disease is very common on cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, and Chinese cabbage, as well as on radish, turnip, and rutabaga. Inasmuch as the causal organism infects many species of crucifers, wild plants and weeds of that family (such as mustards), as well as cultivated ornamentals (wallflower and stock), are affected. The losses

due to clubroot are sometimes very heavy, and the economic importance of the disease is increased by the fact that soil, once infested, commonly remains so for an indefinite period even in the absence of susceptible host plants.

CHARACTERISTICS

The outstanding symptom of clubroot is the abnormal enlargement of the roots (fig. 1). These enlargements may occur on the very small roots, the secondary roots, the taproot, or the underground portion of the stem. The root clubs are often thickest at the center, tapering spindlelike toward either end. The normal processes of the roots are of course disturbed by this malformation. Moreover, as the enlargements are less protected against secondary soil organisms, clubbed roots commonly decay before the end of the season.

In plants in which fleshy roots are normally formed—turnips, rutabagas, and radishes—infection is commonest on the secondary roots. It occurs on the fleshy roots chiefly where the side roots emerge. Therefore, a difference in varieties occurs corresponding to the form of the root. In globe varieties of these crops secondary roots arise chiefly from the nonfleshy taproot, and the edible roots are not commonly infected by clubroot, whereas in the long and half-long varieties, where the secondary-root zones extend approximately half the distance of the fleshy root, the latter is commonly invaded by the clubroot organisms and deformed by club formation.

The effect of the root disturbance is eventually to stunt the plant. This stunting does not always occur promptly, however. A seedbed, for instance, may show no evidence of disease in the aboveground parts of the plants, but when the plants are pulled they may be found to have fair-sized root clubs. Likewise, infection occurring in the main field may easily escape notice because the stunting of the plants is often very slow and gradual. Mildly affected cabbage or cauliflower plants may form fair-sized heads. If the environmental conditions favor rapid development of the disease, the stunting may be sudden and pronounced, and the plants may wilt during the middle of bright days. Permanent wilting may accompany advanced decay of the enlarged roots.

CAUSAL ORGANISM

The parasite associated with clubroot is a minute organism, one of the slime molds (*Plasmodiophora brassicae* Wor.), the spores of which remain in the soil for long periods. With favorable temperature and moisture, some of the spores germinate, and each gives rise to a small motile body which penetrates the underground parts of the host plant. Once within the host, it enlarges, probably divides, and progresses slowly through the tissues. The presence of the parasite stimulates abnormal growth of the affected parts, but the normal development of the water- and food-conducting vessels is inhibited. The clubbed roots therefore do not function properly, and their abnormal growth draws the sugar made in the leaves and diverts it from its normal storage place, such as the cabbage head. Later the clubroot organism divides into innumerable individual spores which

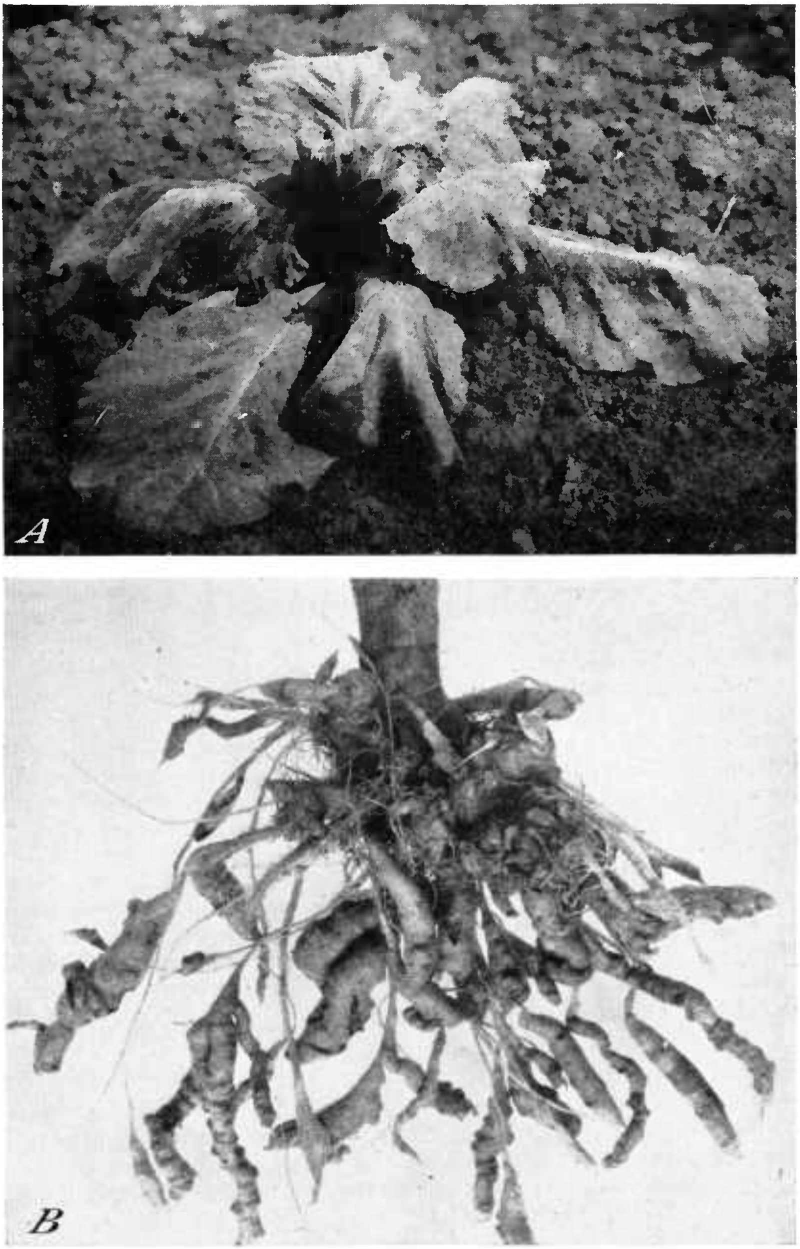

FIGURE 1.—Two phases of clubroot on cabbage. *A*, Wilting of half-grown cabbage plants the roots of which are severely clubbed and the water-conducting vessels thus seriously malformed. Temporary midday wilting is commonly followed by permanent wilting and death. *B*, Malformed roots of cabbage; note the spindlelike shape of the clubs.

are so constituted as to be able to withstand long periods of unfavorable weather. They are returned to the soil when the cabbage roots rot.

CONDITIONS FAVORING CLUBROOT

Even though a susceptible cruciferous plant is growing upon soil infested with the clubroot organism it does not necessarily follow that the plant becomes diseased. The surrounding conditions must be such that host and parasite react together to develop the disease. Clubroot develops over nearly as wide a range of temperature as that at which the host will ordinarily grow, and thus the disease is not restricted to any region on this account. In very dry soil the spores of the parasite fail to germinate, and it is possible to prevent infection by keeping the soil moisture constantly at a low level. However, this is of little practical value, since a rise in soil moisture for as short a time as 18 hours is sufficient to permit spore germination and infection, after which a return to low soil moisture does not prevent club formation.

Acidity or alkalinity of the soil is very influential upon clubroot. The parasite is sensitive to an alkaline condition, and if infectious soil is made alkaline (pH 7.2 or above) and kept uniformly moist little or no infection occurs, and the plants grow normally and remain healthy. This fact is the basis of the long-known beneficial effects of lime as a specific remedy for clubroot. It has been shown recently, however, that the application of lime sufficient to increase the soil pH to 7.2 or higher does not always lead to disease control. This is explained by the fact that although the bulk of the soil moisture is alkaline, the soil-moisture film immediately around the rootlets may be acid, because carbon dioxide is continually being given off by the rootlets. It appears that in moist soil there is sufficient movement of alkaline particles to neutralize the acid promptly, while in drier soil this may not hold. Thus in the latter instance the favorable condition for clubroot-spore germination prevails in that most important region, that immediately around the roots.

The facts just mentioned are extremely important in the control of the disease. They explain why liming is sometimes successful and sometimes not. The effectiveness of this remedial measure varies with the soil type, the season, and the locality, depending upon how completely the external environment permits the protection of the root system from the clubroot parasite.

CONTROL

It has been pointed out that soil contaminated with the clubroot organism usually remains infectious for many years. Crop-rotation systems wherein long intervals between cruciferous crops prevail are not very effective in reducing soil infestation. If possible, it is better to abandon badly infested soil for crucifers for an indefinite period.

The clubroot organism is not carried with the seed. It is carried readily, however, with infested soil, crop refuse, and infected plants from locality to locality and from field to field. Badly infested areas having been abandoned, it is important to prevent the contamination of clean fields. Infested soil is carried readily on farming implements, by man and animals, by surface flood waters, by transplants

from infested beds, and by any propagative plant parts such as potato seed tubers, bulbs, etc. Manure from stock fed on diseased root crops is infectious. By these various means the organism is continually being transported, and such transfers must be checked in order to confine this disease.

The benefits and limitations of liming have already been discussed. Where crucifers are a dominant crop an alkaline soil is desirable. When favorable soil-moisture levels prevail, reduction of clubroot may be expected; furthermore, new contamination of such soils is less likely to occur. It should be borne in mind, however, that neutral or slightly alkaline soils are particularly favorable to potato scab. In areas where high acidity of the soil is essential for scab control, obviously it will not be possible to bring about clubroot control through adjustment of soil reaction.

The use of resistant varieties to control clubroot has limited possibility at present. No varieties of cabbage, cauliflower, kohlrabi, or brussels sprouts are known which show any practically important resistance to this disease. For many years plant breeders in northern Europe have sought to develop rutabagas and turnips that are resistant to clubroot. The Danish Bangholm variety is reported to be resistant in Denmark and Great Britain. The Bruce turnip is resistant in Scotland and New Zealand. However, none of these are satisfactorily resistant on very infectious soil in Sweden. A new highly resistant turnip, Immuna, has recently been developed there.

The fact that certain varieties of turnip and rutabaga are resistant in some localities and not in others leads to the supposition that different strains of the parasite exist in different localities. Little is known about this matter. It appears that most of the rutabaga varieties used in the United States are highly resistant to the parasite as it occurs here; many varieties of turnip are also resistant. The recently introduced Japanese variety, Shogoin, is very susceptible, however, and should be avoided where soil is known to be infested.

The important measures of control may be summarized as follows:

(1) Abandon badly infested areas for cruciferous crops if possible.

(2) Avoid infestation of new areas by selecting clean soil for plant beds; avoid transfer of infectious material from infested areas by implements, farm animals, plants, surface drainage water.

(3) If compatible with the well-being of other crops in the rotation, keep the soil alkaline.

(4) Use resistant varieties of turnip and rutabaga.

ROOT KNOT

CHARACTERISTICS

Root knot is most common on crops grown on the light sandy soils in the South; in the Northern States it occurs chiefly in greenhouse soils. It affects a large number of crop plants and weeds. While the most distinctive symptoms are root malformations (fig. 2), the indirect effect is a stunted, sickly appearance of the above-ground parts of the host plant.

In an attempt to distinguish between root knot and clubroot some confusion is likely to result. Although the organisms associated with the two diseases are quite different, the effects produced on the roots bear some points of resemblance. (Compare figs. 1, *A*, and 2.)

Root knot is generally characterized by smaller swellings than clubroot, and infection as a rule is more uniformly distributed on the lateral feeding roots. If, when the swellings on the roots are broken open, pearly white bodies about the size of a pinhead are found, root knot is to be suspected. These white specks within the swelling are the enlarged egg-bearing female nematodes or eelworms that cause the disease. The interior mass of clubroot is slightly pinkish or brick colored.

FIGURE 2.—Root knot of cabbage.

CONTROL

Crop rotation has been found to be the most practicable means of controlling root knot. The aim is to use crops immune or resistant to the disease, in order to starve out the eelworms. When this method is employed, a rotation of at least 3 years, accompanied by clean cultivation to keep down weeds, should be practiced. There are more than 500 different species of plants already known to be susceptible to root knot, among which are many cultivated plants and numerous weeds.

The following list of the more important immune or highly resistant crops will be of assistance in planning rotations for the reduction of the trouble. If nematodes occur in the seedbed or in the greenhouse, the soil should be sterilized by live steam.

Crops largely or entirely immune to root knot

Barley.
Beggarweed, Florida.
Chufa.
Corn.
Cowpea:
  Brabham.
  Iron.
  Monetta.
  Victor.
Crabgrass.
Grass, Bermuda.
Grasses (nearly all).
Kafir.
Millets (nearly all).
Milo.
Oats, winter.
Peanut.
Rye.
Sorghum.
Soybean (Laredo variety only).
Velvetbean.
Wheat.

YELLOWS

The disease called yellows is confined to members of the cabbage tribe (cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, kale, and collards). It is especially destructive to cabbage and constitutes a serious menace to this crop from Long Island to Colorado, including the southern parts of New York, Michigan, Wisconsin, and Minnesota, and southward as far as cabbage is grown as a summer crop. It is most prevalent in warm weather and does little or no damage in the extreme northern sections or along the northern Pacific coast. Winter-grown cabbage in the Southern States is ordinarily not severely affected. In the latitude of New Jersey and Maryland westward through Ohio, Indiana, Illinois, southern Wisconsin, and Iowa, yellows remained the greatest hazard to cabbage growing until resistant varieties were developed. In thoroughly infested soils it is not uncommon for complete destruction of susceptible varieties to occur.

CHARACTERISTICS

Plants infected with yellows usually show the characteristic symptoms in 2 to 4 weeks after being transplanted, but the disease may appear in the seedbed. The first sign is the lifeless, yellowish-green color of the foliage. Sometimes the yellowing is uniform; more often it is more intense on one side, causing a lateral warping or curling of the stem and the leaves (fig. 3). The lower leaves become yellow first, and the appearance of symptoms progresses upward. As the yellowed tissue ages it turns brown and becomes dead and brittle. Affected leaves drop prematurely, and normal growth is distinctly retarded. The water vessels in stems and leaves of diseased plants become yellow to dark brown. In many respects the disease resembles black rot (p. 15) and is often confused with it. One fairly reliable point of distinction is that in black rot the veins become black rather than brown and the smaller veins of diseased leaves are much more generally discolored.

The rapidity with which yellows progresses depends upon the degree of susceptibility of the host plant and the favorableness of the environment. In the latitude where yellows is most severe the conditions optimum for the development of the disease usually prevail during the first 3 or 4 weeks following the transplanting of the main crop of cabbage. The disease may then progress so rapidly that most susceptible plants die within 2 weeks. Many continue a sickly existence for a month or more, and a few live through the summer, heading imperfectly. In the crop planted for early cabbage heads, the conditions favorable for yellows may not appear until the crop is approaching maturity; thus very susceptible early varieties often escape the disease.

CAUSAL ORGANISM

The yellows organism is a fungus (*Fusarium conglutinans* Wr.) which is closely related to, but distinct from, those causing wilt of cotton, tomato, watermelon, cowpea, garden pea, and aster. It consists of microscopic threads (mycelium) and grows in the soil and on dead plant refuse. It produces two types of microscopic

seeds or spores, one type being thin-walled and short-lived (conidia), the other heavy-walled and capable of withstanding long periods of unfavorable temperature or drought. Many plant parasites do not persist long in the soil in the absence of their host, but the yellows organism, like that of clubroot, remains viable in the soil for many years. In fact there is reason to believe that the former and its related wilt fungi not only persist in the soil, but actually grow and increase in many soils quite independently of their respective host plants.

The yellows organism enters the plant almost entirely through the region of the young rootlets. It may enter through wounds in

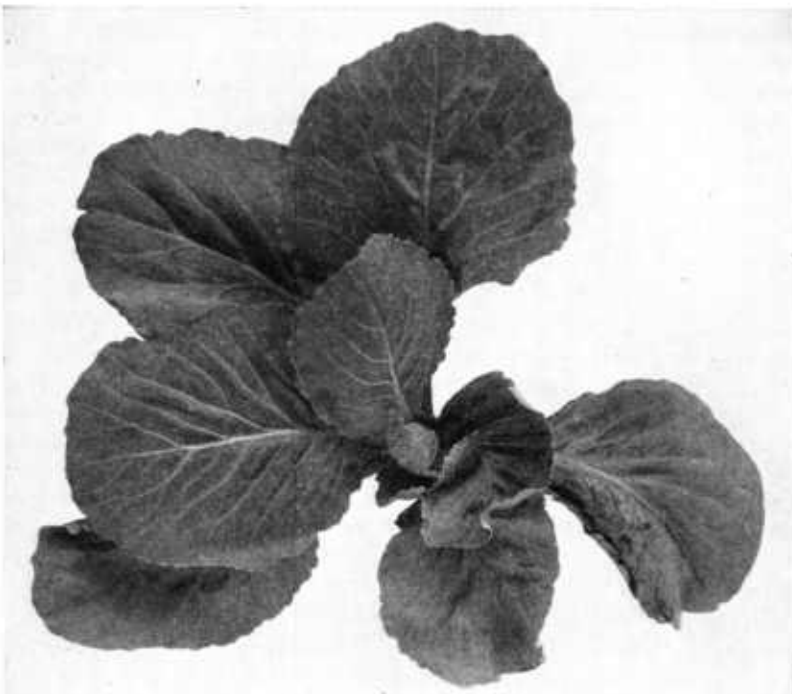

FIGURE 3.—A partly grown cabbage plant showing distortion of the lower leaves due to the development of yellows. Note the consequent dwarfing of the leaf on one side and the normal growth on the other.

older roots incurred at the time of transplanting. It penetrates the young root tissue and migrates directly to the water-conducting vessels. It then progresses up the root and stem into the leaves, confining itself to the vessels until the plant or its parts die, when the mycelium may permeate the dead tissue and produce conidia on the surface. Occasionally conidia are produced within the water vessels. The characteristic browning of the vessels is associated with fungal invasion. Migration is largely upward, and little lateral spread from vessel to vessel occurs. The unilateral development of leaf symptoms and of those on the plant as a whole is thus associated with the invasion of certain vessels and the freedom of

others from the fungus. The browning of vessels and the yellowing of leaves commonly occur well in advance of the penetration of the fungus. In fact the disease condition is apparently not due to the plugging of the vessels by the fungus, but rather to the toxic substances produced in the vessels concurrent with fungus invasion and carried to the stems and leaves by water currents.

CONDITIONS FAVORING YELLOWS

As already pointed out, yellows is a warm-weather disease. It is almost completely checked when the average soil temperature is below 60° F. Its appearance is hastened and its severity increased as the air and soil temperature averages rise above that point. When the average temperature is 90° or above, yellows development is retarded, but since this condition does not prevail for long intervals in sections where cabbage is profitably grown there is no practical check of the disease by higher temperatures.

Soil moisture and soil reaction have little influence on yellows, and the fungus establishes itself readily in a wide range of soil types.

HOST RESISTANCE TO THE YELLOWS FUNGUS

Varieties of cauliflower, broccoli, and brussels sprouts naturally have a high degree of resistance to yellows. Cabbage, kohlrabi, and most kale varieties (with the exception of those recently developed for yellows resistance) are generally very susceptible to the disease.

In most of them, however, at least a small percentage of the plants survive on thoroughly infested soil under optimum conditions for the disease. These resistant survivors have become the basis of selection of resistant varieties of cabbage, many of which are now in commercial use.

In the course of breeding for yellows resistance, two types of resistance have come to be recognized. Since they are important in determining the value of a given yellows-resistant variety their main points of distinction are indicated; they are referred to as type A and type B (fig. 4).

Since type A is controlled by a single hereditary factor it is relatively simple to secure lines that run true for this type of resistance, and in such lines the resistance remains fixed if outcrossing with other varieties is not permitted. Plants that have type-A resistance develop no typical symptoms of yellows even at high temperatures.

Type-B resistance is controlled by a complex set of hereditary factors, and it is very difficult, if not impossible, to fix this character in a variety so that it will run true through successive generations. Moreover, plants containing type-B resistance differ from each other in the "dosage" of resistance they contain. As the average soil temperature rises, this type of resistance is progressively less effective, until at 77° F. (constant soil temperature) or above, type-B-resistant plants succumb with typical yellows on infested soil while type-A-resistant plants remain perfectly healthy.

In the field, therefore, type-A-resistant varieties remain free from yellows even during very warm summers. Type-B-resistant varieties are commercially successful in moderately warm seasons, but as the

temperature increases a large percentage of individual plants show varying degrees of disease development until heavy losses may result, if a protracted high-temperature interval prevails.

It is obvious, therefore, that type-A-resistant varieties are most valuable, and these are being developed to meet the varied needs as rapidly as time and facilities permit. It is usually difficult to distinguish between type-A- and type-B-resistant plants in the field, since they can only be separated with certainty if grown in the greenhouse on infested soil held at a constant temperature of 77° F. This method is used in breeding new varieties and can be used also to determine what percentage of seeds in a commercial resistant variety carry type-A resistance.

CONTROL THROUGH RESISTANT VARIETIES

The yellows organism is not seed-borne but, like the clubroot organism, is readily transported by man, animals, implements, plants,

FIGURE 4.—Resistance to cabbage yellows as shown in strains grown on naturally infested soil. In the center are two rows of Penn State Ballhead, a very susceptible variety; at the left are two rows of Wisconsin Ballhead, which is perfectly free from yellows, since all the plants carry type-A resistance; at the right is Wisconsin Hollander, which contains only type-B resistance. There is a much better stand than in the Penn State Ballhead, although a large percentage of the plants show mild to moderately severe stages of yellows.

bulbs, seed tubers, surface drainage water, and plant refuse. Since the organism persists indefinitely in the soil, crop rotation is ineffective. So far as cabbage culture is concerned, the disease has been brought under successful control by the development of yellows-resistant varieties. Since a wide range of resistant types now exist they should be used exclusively in those regions where climatic conditions permit the development of the disease.

Resistant varieties in commercial use are described in the following paragraphs. It will be seen that they range from early- to late-

maturing types. The designation in days accompanying each variety refers to the average number of days elapsing from the time transplanting occurs to the maturing of the heads when the plants are set out in early June in southeastern Wisconsin. This interval will vary with the season, locality, and method of propagation. It is useful here, chiefly in giving a basis for comparing the relative rates of maturing of the various sorts.

Jersey Queen.—55 days. Developed by the United States Department of Agriculture and the Wisconsin Agricultural Experiment Station. Introduced in 1932, it was selected from Jersey Wakefield variety and remains practically identical with it in type and season. Heads are pointed. Plants are small and permit close planting. The strain conforms to the smaller headed strains of Jersey Wakefield. Authentic seed lots should test 98 to 100 percent type-A resistance (fig. 5, *A*).

Resistant Detroit.—55 days. Introduced in 1936 by Ferry Morse Seed Co. Selected from Copenhagen Market. It conforms in type with acceptable stocks of the latter. Heads are globular to slightly flattened. The strain matures a little later than the earliest strains of the commercial variety. Tests show it to contain about 80 percent type-A-resistant individuals.

Racine Market.—60 days. Developed by the Department of Agriculture and the Wisconsin Station. Introduced in 1935. Selected from Copenhagen Market. This variety is generally similar in leaf and head type to Copenhagen Market except for leaf color, which is blue green rather than yellow green. It is a few days later and under favorable growing conditions produces a larger head. Authentic stocks test 98 percent type-A resistance (fig. 5, *B*).

All Head Select.—65 days. Developed by the Department of Agriculture and the Wisconsin Station with the aid of the National Kraut Packers' Association. Introduced in 1927. A flathead type selected from All Head Early. It is a midseason type used for the southern shipping market and for early sauerkraut manufacture in the North. Authentic stocks test 95 to 100 percent type-A resistance.

Marion Market.—70 days. Developed under the same auspices as All Head Select. Introduced in 1927. Selected from Copenhagen Market but distinct from that variety in its later maturity, greater size of plant and head, and bluer cast of foliage. It is widely used as a midseason cabbage for market and sauerkraut in the North and as a winter shipping cabbage in the South. Authentic stocks test 95 to 100 percent type-A resistance (fig. 5, *C*).

Globe.—75 days. Developed under the same auspices as All Head Select. Introduced in 1927. Selected from Glory of Enkhuizen. A midseason, roundhead type requiring a few days longer to mature than Marion Market but suited to the same market requirements. It has a relatively shorter core than other roundhead varieties. Authentic stocks contain 95 to 100 percent type-A resistance (fig. 5, *D*).

Wisconsin Ballhead.—85 days. Developed by the Department of Agriculture and the Wisconsin Station. Introduced in 1935. Selected from Danish Ballhead. It is practically identical with the

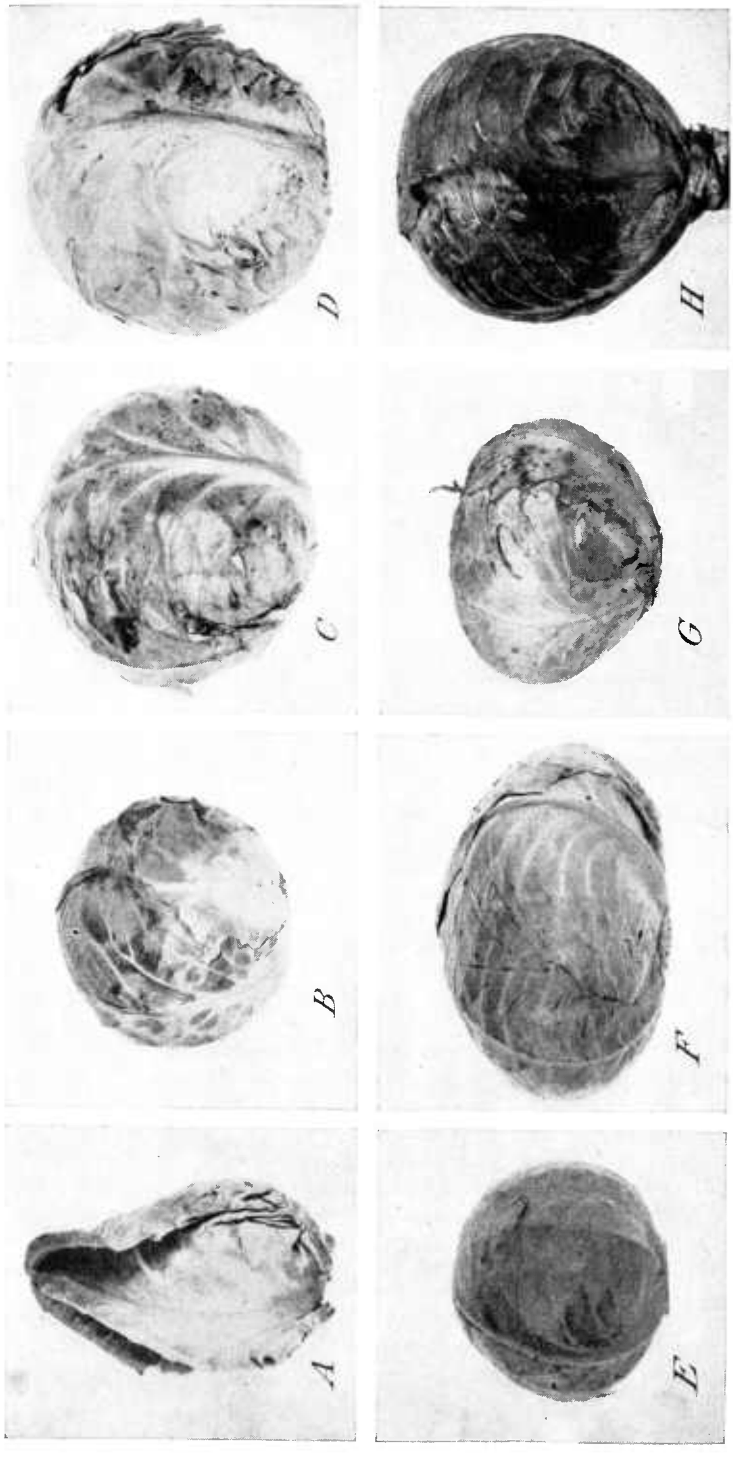

FIGURE 5.—Heads of yellows-resistant cabbage varieties: *A*, Jersey Queen; *B*, Racine Market; *C*, Marion Market; *D*, Globe; *E*, Wisconsin Ballhead; *F*, Wisconsin All Seasons; *G*, Wisconsin Hollander; *H*, Red Hollander.

latter in type and season; roundhead; short stem; blue foliage. Suitable in the North for early-autumn shipping, and when planted so as to mature late enough, it is suitable for storage. The plant is not as large nor does it produce as large a head as Wisconsin Hollander and should be planted closer on that account. Authentic stocks should test close to 100 percent type-A resistance (fig. 5, *E*).

Wisconsin All Seasons.—90 days. Developed by the Wisconsin Station. Introduced in 1921. Late-maturing, drumhead variety similar to All Seasons. It is suitable for late-fall market and is used somewhat for the southern winter crop; however, it is used most widely in the North for the late pack of sauerkraut. Most of the individual plants contain type-B resistance; up to 20 percent of them contain type-A resistance. Under very high summer temperatures it may show a considerable percentage of yellows. Strains containing 100 percent type-A resistance are being developed (fig. 5, *F*).

Wisconsin Hollander.—100 days. Developed by the Wisconsin Station. Introduced in 1916. Selected from Danish Ballhead. It is 10 to 14 days longer in season than the latter and produces a larger, flatter head. It is an excellent storage cabbage and is used widely in the northern part of the yellows zone. The resistance is all of type B, and the variety is therefore not suitable in the warmer portions of the yellows zone where under extreme warmth it may succumb rather heavily to yellows (fig. 5, *G*).

Red Hollander.—100 days. A roundhead, late red sort developed by W. J. Hansche of Racine, Wis. It contains mostly type-B resistance but is quite satisfactory in the northern part of the yellows zone. It is suitable for winter storage (fig. 5, *H*).

Bugner.—110 days. This variety, one of the first resistant sorts developed in North America, was selected by a Mr. Bugner, a gardener in the vegetable-growing section near Chicago, Ill., where it has been used extensively for 20 years or more. It is a Ballhead or Hollander type and somewhat longer in season than Wisconsin Hollander. It produces very large, slightly flattened heads that have excellent keeping quality. The resistance in Bugner is all of type B, and different strains vary in the degree of resistance they possess. In extremely warm seasons the variety often shows high percentages of yellows.

BLACK ROT

Black rot occurs on all the cultivated crucifers and may affect some of the wild species. It finds congenial climatic conditions in many localities, and since the organism is seed-borne it has been distributed to many parts of the world. Since it persists indefinitely in the soil and depends upon the seed for distribution, the disease is decidedly spasmodic. When it becomes established early in the growing season and favorable environment prevails, it may become extremely destructive, rendering a large percentage of cabbage plants incapable of producing marketable heads and making the remainder of the crop unsafe for storage or shipment. Cauliflower is one of the most susceptible hosts, and it requires the greatest care and precaution to grow it free from this disease.

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CHARACTERISTICS

Plants may be affected at any stage of their growth. The storage organs below ground of crucifers that have fleshy roots (turnips, rutabaga, radish, horseradish) may be affected and a dry rot occur. This is commonly followed by the soft-rot disease (p. 22). Otherwise, black rot is a disease of the above-ground organs.

Infection takes place primarily through water pores at the margin of the leaf. The progress of the disease from this point can frequently be traced through the veins of the leaf (fig. 6, *A*) by the blackening of the bundles. The marginal infection is later followed by a browning and drying up of the infected areas of the leaf. Invasion also commonly occurs through wounds made on the leaf by biting insects. The organism progresses down the leaf to the main stem, where it may advance up or down. As it goes up the stem younger leaves are invaded. The affected bundles in leaf or stem are easily recognized, upon cross-sectioning, by their blackened appearance and often can be traced throughout individual leaves of the cabbage head (fig. 6, *B*). If plants are infected while still young, dwarfing or one-sided growth commonly occurs. Affected leaves drop prematurely. In extreme cases heading is prevented. Black rot does not cause a soft rot of affected cabbage or cauliflower heads, but it opens the way for soft rot bacteria (p. 22); consequently, soft rot symptoms are common in association with black rot. For this reason it is dangerous to store cabbage heads or turnip or rutabaga roots from fields where black rot occurs.

There are some points of resemblance between yellows and black rot which often lead to confusion. Both cause discoloration of the bundles, and both may bring on one-sided development of the leaves or of the whole plant. In the main, the bundles affected by black rot are black, and in the later stages they are commonly surrounded by cavities due to the break-down of surrounding cells. With yellows the bundles are brown, and no cavities occur.

CAUSAL ORGANISM

The black-rot organism is one of the bacteria (*Bacterium campestre* (Pammel) E. F. Smith). These minute organisms are carried about by insects, spattering rain, surface drainage water, and possibly by wind, or with wind-borne particles of dust. They are able to swim about in liquid, and when they come in contact with drops of liquid that collect on the margins of leaves or about insect wounds they enter the water pores or wounded tissue. They are able to penetrate the tissue until they reach the conducting vessels, and from then on they multiply in and progress chiefly through this channel. They may be carried over from year to year in or on seeds from infected host plants or in diseased plant refuse.

CONDITIONS FAVORING BLACK ROT

In crops started in seedbeds the initial spread of the parasite usually occurs in that location. Occasional plants become diseased from seed or soil, and in them the germs multiply and become available for spread. Spattering water from rainstorms or artificial

FIGURE 6.—Black rot of cabbage: *A*, Symptoms which result from invasion of the marginal water pores and migration downward through the water vessels; *B*, vessel blackening in an infected leaf of a mature head, brought about by the migration of the causal organism up the stem into the head leaves.

sprinklers is the chief means of dissemination. The amount of such spread determines how widely the plants are infected before they are transplanted. Infected lower leaves usually drop off, and plants commonly show little or no external sign of the disease, though internally infected when transplanted. Infected plants may grow normally with little or no external sign of disease for 3 to 6 weeks after they are transplanted; after that period the lower leaves gradually develop symptoms owing to the migration of the organism from the main stem. Thus fields of cabbage or cauliflower may rather suddenly show large percentages of plants with black rot in midseason. The epidemic is due to favorable conditions for early spread in the seedbed and the slow subsequent development of the parasite in the plants.

Black rot is practically absent in the Puget Sound cabbage-seed-growing region. Its retardation is attributed to the lack of heavy spattering rains during the period in which cabbage plants are in the seedbed and the consequent unfavorable conditions for the spread of the parasite. Cabbage seed from that area is generally free from the black rot organism.

CONTROL

The major steps in the control of black rot are as follows:

(*1*) Clean seed. Puget Sound grown cabbage seed may be used without treatment. In all other cases treat the seed before planting with the hot-water treatment described on page 2.

(*2*) Clean seedbed. The black-rot organism lives in the plant refuse in the soil during one and possibly two northern winters. It is therefore essential to provide two noncruciferous crop seasons between those in which the soil is used for that purpose or to sterilize the soil between crops.

(*3*) If seedbeds are watered artificially, avoid sprinkling the foliage since to do so aids in disseminating the causal organism. It is preferable to irrigate in furrows between the rows.

(*4*) Practice rotation on the main field so that at least 2, and preferably 3, years elapse between cruciferous crops.

BLACKLEG

Blackleg is important only on members of the cabbage tribe, but it may attack turnips and rutabagas. A strain of the blackleg organism attacks the latter two crops in Europe and in New Zealand, causing a serious dry rot in storage. This phase has not been reported in the United States, and the American blackleg disease is found most commonly on cabbage, cauliflower, broccoli, brussels sprouts, and occasionally on kohlrabi and kale. When the disease gains a start in the seedbed it may be very destructive in the main field.

CHARACTERISTICS

The earliest conspicuous symptoms occur in the seedbed 2 or 3 weeks before transplanting time. Spots occur on leaves and stems. The leaf spots appear as inconspicuous, indefinite pallid areas that gradually become well-defined spots with ashen-gray centers in which innumerable black dots much smaller than a pinhead are

scattered irregularly (fig. 7). These are the fruiting bodies (pycnidia) of the fungus. Similar spots occur on the stem, where they are sunken and are often surrounded by a purplish border. The stem lesions gradually enlarge after the plants are removed to the main field, extending to the underground portions. In fact, incipient, invisible infections at transplanting time gradually develop into subterranean stem and root lesions. The fibrous root

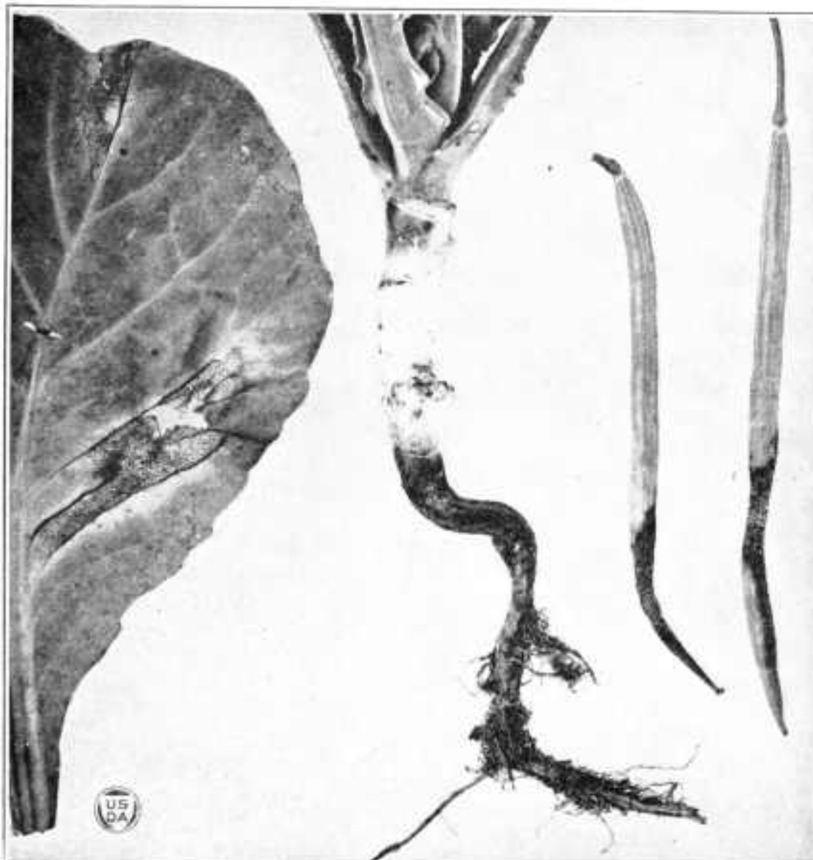

FIGURE 7.—Blackleg of cabbage. Note injury to and blackening of the lower main stem and main root; fibrous roots are destroyed. On above-ground parts (stem, leaf, and seed pod) lesions are ashen gray, sometimes with purple borders, and covered with small black fruiting bodies, which are partially embedded in the dead tissue.

system may be largely destroyed, although new roots sent out above the lesions serve to keep the plant alive. Often badly affected plants survive until fair-sized heads form when they topple over as the increasing top weight overbalances the gradually decaying root anchorage. Many plants wilt abruptly and die. The wilting leaves tend to remain attached to the stem, instead of dropping as in black rot and yellows. As root corrosion progresses, the still-turgid plants often show a reddish color of the outer leaves, particularly near the margins. Other types of root injury may cause similar

coloration, however. Pycnidia are not common on subterranean parts until the plants are dead and the succulent tissue has completely decayed.

Leaf spots continue to appear, their number depending on favorableness of the environment. The fungus may invade heads in storage, but it does not cause serious decay. It attacks the branches, leaves, and pods of seed plants and invades the seeds. Many seeds, when attacked in their early formative period, become shriveled and nongerminable; others, only slightly affected, carry dormant mycelium in the seed coat and remain viable. Young seedlings are attacked either on the cotyledon, which commonly carries the infected seed coat above ground, or at the base of the stem (hypocotyl) if the seed coat remains below the ground. In any case seedlings attacked early die promptly and furnish an early crop of pycnidia, from which the spores may spread to surrounding plants.

CAUSAL ORGANISM

The causal organism is a parasitic fungus (*Phoma lingam* (Tode) Desm.). It is carried in the seed and persists on plant refuse for 1 or 2 years. Damage to the host is done by the mycelium that penetrates the tissue, killing as it goes. The mycelium in the dead tissue gives rise to the dark pycnidia, which are flask-shaped, with an opening to the exterior of the leaf or stem. Myriads of thin-walled spores are formed within the pycnidia, where they remain embedded in a gelatinous matrix during dry weather. Moisture on the lesion in the form of rain or dew is absorbed by the matrix, which expands rapidly, forcing its way through the opening of the pycnidium to the exterior, carrying spores with it.

The spores germinate within a few hours and penetrate the host if moisture is present. If the plant surface dries off quickly the spores die. It is thus evident that a moist period of several hours is essential for spore expulsion and reinfection, while spattering rain is essential to carry the viable spores from diseased to healthy plants.

CONDITIONS FAVORING BLACKLEG

Initial infection in the seedbed starts with occasional plants infected from the seed or soil. The fungus usually kills them promptly and fruits. Further spread is dependent on moist periods and spattering rain. Epidemics are usually to be traced to rapid spread in the seedbed. This often occurs just before transplanting, and the new infections, being invisible, appear later in the infected field. As pointed out in the case of black rot (p. 15) the Puget Sound cabbage-seed-growing section fortunately has climate during the seedbed period very conducive to checking the spread of blackleg from any initial centers; consequently, the cabbage-seed crop in this section has remained consistently free from blackleg.

CONTROL

The same measures of control outlined for black rot (p. 18) are effective in the control of blackleg.

THE RHIZOCTONIA DISEASE

The rhizoctonia fungus is widely distributed in the soil. It attacks a great many species of plants, causing a variety of pathological effects; but probably it is made up of numerous strains, which vary in the hosts that they select. The form which attacks the potato, for instance, does not affect crucifers and vice versa. In its many phases it is of major importance on cruciferous crops.

CHARACTERISTICS

Cruciferous plants are attacked at different stages, and the symptoms will be grouped accordingly.

Damping-off.—Rhizoctonia is one of the most common fungi that attack the young seedling, invading it at the base of the young stem (or hypocotyl) or at the soil line. The tissues become water-soaked, and rapidly collapse, and the tender young plants topple over and die. A number of other soil fungi affect young seedlings in a similar manner.

Wire stem.—When young seedlings are attacked less vigorously or slightly later they have a much greater chance of warding off the fungus. This is occasioned by the fact that the young stem has begun to thicken and grow in diameter and to slough off its outer cells. Plants at this stage previously attacked by rhizoctonia are brownish to black just above and below the soil line; the stems are usually somewhat smaller than normal but tough and woody. This phase is known as wire stem. Affected plants may recover and grow normally, but under some conditions the fungus may continue to retard their growth after they are transplanted.

Bottom rot.—Bottom rot occurs in midseason, either as a carry-over from wire stem or from new infection. The lower leaves droop, decay, and turn dark but do not drop. Plants may recover and produce normally. In cabbage, bottom rot may develop into head rot.

Head rot.—Head rot of cabbage develops between early head formation and maturity as a dark firm decay at the bases of outer leaves and heads (fig. 8). The outer leaves of the head become wilted and pallid and brown to black near the main stem. Mycelium becomes conspicuous on decayed tissue and between the head leaves, on which it produces dark sunken spots. Firm, persistent dark decay continues in storage and transit.

Root rot.—Root rot of turnip, rutabaga, and radish occurs before harvest and in storage. In greenhouse culture of radishes a rather soft decay of partly grown roots is common, in which gray surface mycelium and dark-brown kernellike bodies (sclerotia) form. A similar brown and spongy decay occurs on turnip and rutabaga roots, particularly in storage. The cobwebby mycelium and brown sclerotia help to distinguish the disease.

CAUSAL ORGANISM

The causal fungus (sterile form, *Rhizoctonia solani* Kühn; spore-forming stage, *Corticium vagum* Berk. and Curt.) is a common soil fungus. Its occurrence as a parasite depends largely on the susceptibility of the host and the favorableness of the environment. It attacks chiefly young succulent tissue and dormant storage tissue.

The mycelium is long-lived, and as the food in the decaying tissue becomes exhausted, it rounds up into dense brown kernellike bodies (sclerotia), which may resist unfavorable conditions for an indefinite period. Spores are seldom formed. Occasionally a superficial white mycelial weft on the lower side of leaves near the soil bears thin-walled short-lived spores. As pointed out (p. 21), the fungus has a number of strains that are specialized on certain groups of plants.

CONTROL

(1) When plants are grown in hotbeds or coldframes treat the soil with steam or formaldehyde. Crucifers are very sensitive to the latter; allow the soil to stand 2 or 3 weeks before using.

FIGURE 8.—Rhizoctonia head rot of cabbage.

(2) Mercuric chloride (1–2,000) as a drench at the base of plants in the seedbed as used to kill maggot eggs is helpful in reducing wire stem.

(3) Sort out wire stem plants when transplanting.

(4) Avoid short rotations of crucifers to reduce bottom rot, head rot, and root rot.

BACTERIAL SOFT ROT

CHARACTERISTICS

The loss from bacterial soft rot alone or in combination with other rots is considerable both in storage and in transit. It is occasionally destructive in the field, especially following black rot. Freezing injury is commonly followed by soft rot.

Soft rot of cabbage is characterized by a soft, mushy, almost slimy decay, which after entering, generally at the surface or base of the head, spreads rapidly throughout the whole plant. The soft rot

bacteria as a class are marked by their ability to destroy plants very quickly under favorable temperature and moisture conditions. They seldom affect uninjured plants, as they require a wound or other injury to gain a foothold, or they appear in conjunction with the black rot or black mold troubles. Infection takes place in the field where considerable damage may be occasioned, but the greatest destruction to this crop is caused in the cabbage storage houses or in transit. Under improper storage conditions the disease spreads rapidly, frequently covering all of the outer leaves and necessitating repeated and excessive trimming (fig. 9). Soft rot is distinguished from other head rots by a characteristic offensive odor given off from the decayed tissue.

FIGURE 9.—Soft rot developing on stored head of cabbage.

CAUSAL ORGANISM

Soft rot in cabbage and related crops is due to bacteria belonging to a group usually referred to as the soft rot bacteria (*Bacillus carotovorus* L. R. Jones is a common example), which may attack carrots, turnips, celery, and other vegetables.

Although these bacteria are universally present they require special conditions in order to gain a foothold in plant tissue. Not only are wounds in the tissue necessary, but the conditions must be such that the wounds are not corked over before the soft rot sets in. High humidity retards cork formation and is thus favorable to soft rot. The gnawing action of maggots keeps the tissue freshly wounded and predisposed to soft rot. Maggot larvae ingest the bacteria, and they remain in their bodies until the adult fly is formed; the fly carries the bacteria to new locations and lays contaminated eggs on healthy plants. Newly hatched maggots thus are provided with soft rot bacteria as they begin to feed. In fact, the bacteria aid the larvae by making the raw plant tissue more digestible. Cabbage plants approaching the heading stage are often attacked by maggot larvae on the main stem at the base of the head. This insect injury may become the forerunner of soft rot in the field.

CONTROL

Cabbage and other crops in preparation for storage or shipment should be carefully selected and so handled that they will be injured as little as possible and all surface moisture allowed to evaporate.

Temperatures slightly above freezing and adequate ventilation to prevent high relative humidity are advisable. The same precautions should be observed in long-distance transit.

WATERY SOFT ROT

CHARACTERISTICS

Watery soft rot is most common in the Gulf coast region, where it occurs on crucifers and many other vegetable crops, especially lettuce, celery, cucumber, and carrot. The earliest symptoms of the disease known as "drop" are indicated by water-soaked areas over the stem and lower leaves. The wilting of the lower leaves is followed by the whole plant finally collapsing into a shapeless mass. The plant may succumb to the disease in a few days, or it may live from 1 to 2 or more

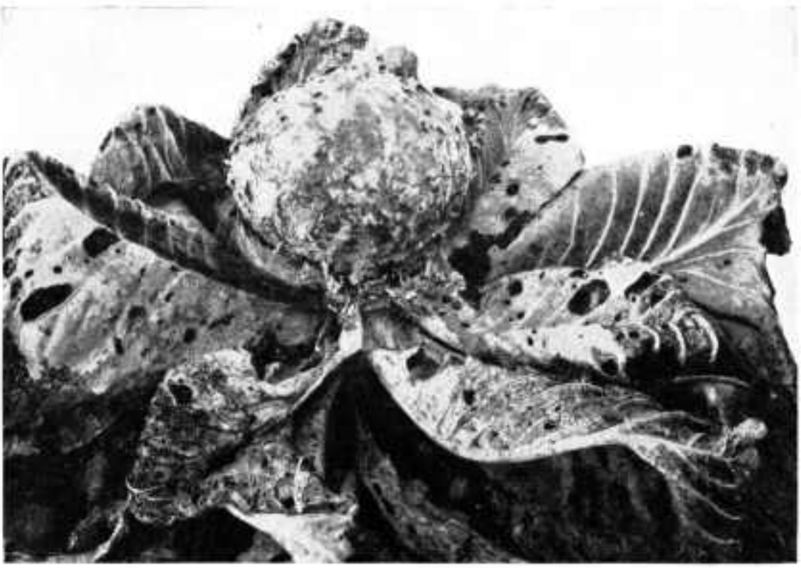

FIGURE 10.—Watery soft rot of cabbage.

weeks. In and about the decayed region a dense white cottony mass of mycelium accumulates. In the later stages of the disease irregularly shaped, hard, black bodies, the size of a mustard seed or larger, are to be found scattered among this cottony mass. These bodies are almost sure evidence of the disease (fig. 10).

Decay of the harvested crop may continue and, in fact, new infection may later occur in plant parts that appear healthy at harvest time. This is usually merely the progress of incipient infections to visible size. The fungus causes a soft rot of storage organs such as cabbage heads, turnip roots, etc., which may be distinguished from bacterial soft rot of crucifers by the lack of sulphurous odor, the presence of cottony mycelium in the decayed tissue, and the fact that the water drains away promptly from the rotting tissue, whereas in bacterial soft rot it is retained in a slimy mass. The latter is thus often referred to in the market as slimy soft rot and the former as watery soft rot.

CAUSAL ORGANISM

The causal fungus (*Sclerotinia sclerotiorum* (Lib.) DBy.) forms a coarse white growth in and about the decayed region of the plant that it attacks; later the hard black bodies heretofore mentioned develop from the mycelium, and serve to carry the fungus during periods of unfavorable environment. In the spring they send up small mushroomlike bodies bearing microscopic spores in abundance which are discharged into the air, and when they come in contact with the moist surface of the host plant they germinate and cause infection.

CONTROL

Control of this disease is difficult. Diseased plants should be removed early. Rotation with crops not attacked by the fungus, such as corn, cotton, crotalaria, peanuts, and sweetpotatoes, is advisable.

BLACK LEAF SPOT

CHARACTERISTICS

Black leaf spot, sometimes called black mold or brown rot, occurs as a leaf spot of cabbage, cauliflower, collards, and a number of other crucifers. It also causes a mold of cabbage heads in storage and a brown rot of cauliflower heads in transit. As a leaf disease it is ordinarily of minor importance, but in storage or transit the organism may be very destructive.

In the field it appears on the lower or outer leaves of the maturing plants as distinct roundish black spots commonly marked with concentric brown zones (fig. 11, *B*). These spots vary from one-fourth to one-half inch or more in diameter. They are distinguished from blackleg spot or ring spot by the absence of the numerous dots (pycnidia) in the diseased area. In storage these spots may blend together on cabbage heads until the outer leaves are covered and entirely blackened by the moldy development. On the curd of cauliflower the disease appears as brown spots which turn olive green with age.

CAUSAL ORGANISM

The disease is caused by a fungus[1] which overwinters on cabbage refuse or on the seed. The black mold that develops on the leaf spots or on cabbage or cauliflower heads consists largely of the dark-colored spores of the organism. These are readily disseminated by wind or water, and they germinate in water, thus invading healthy plants and causing new infections.

CONTROL

Black leaf spot ordinarily is not sufficiently important in the field to warrant the practice of specific remedial measures. The mercuric chloride treatment is not effective; and the hot-water treatment recommended for blackleg (p. 2) is necessary to rid the seed of the organism. Because the disease is most destructive in storage and

[1] The common organism associated with the disease is *Alternaria brassicae* (Berk.) Sacc. Another closely related species may also cause similar symptoms.

transit, care should be taken to handle the crop so as to minimize the trouble. Heads should be handled carefully to avoid bruising, and surface moisture should be allowed to evaporate before storage. The storage house should be kept at 33° to 34° F. and ample ventilation provided to reduce humidity.

RING SPOT

CHARACTERISTICS

Ring spot is most prevalent in North America on the Pacific coast, where it affects cauliflower, cabbage (including seed plants), kale, and certain other crucifers. It appears in the early stages as dark-

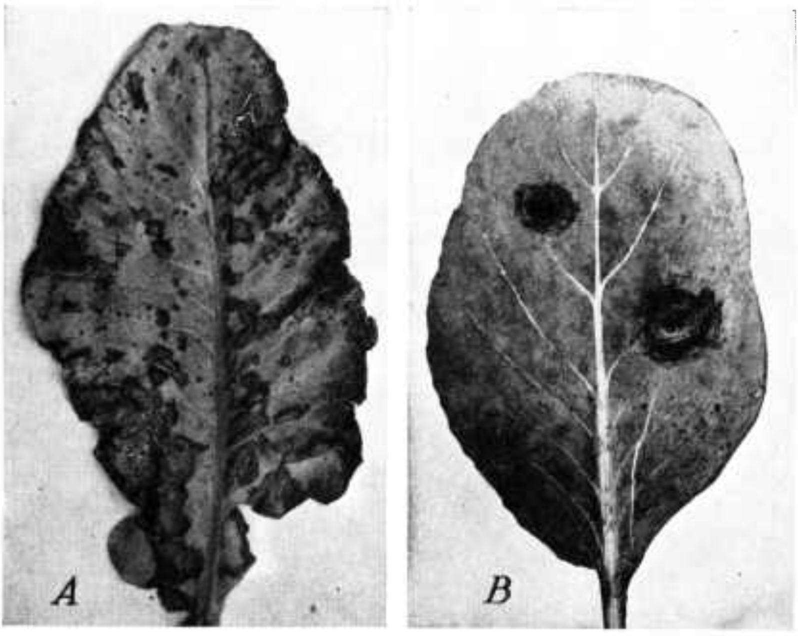

FIGURE 11.—Leaf spots often confused with blackleg spots. *A*, Ring spot on cauliflower. The pycnidia are smaller and more closely crowded than those of blackleg. *B*, Black leaf spot of cabbage. The black spores are superficial and may be rubbed off. The groups of short dark threads on which the spores are borne remain intact and may be confused with pycnidia. They are often arranged in concentric rings.

purple spots, which gradually enlarge, often becoming an inch or more in diameter on the leaves (fig. 11, *A*). The older spots are dark brown with light-green borders. In advanced stages minute black specks appear in the dead portions of the spot, resembling very much those described in the case of blackleg. They are to be distinguished from the latter by being much smaller, more numerous, and thus more closely crowded. The disease appears on the stems and pods of the seed plants as small spots or as long purple streaks. It is sometimes destructive to the cabbage-seed crop in the Puget Sound section. The chief damage is done to cauliflower, on which ring spot causes defoliation and losses in transit.

CAUSAL ORGANISM

Ring spot is due to a fungus (*Mycosphaerella brassicicola* (Fr.) Lindau) similar in appearance and general character to that causing blackleg. It overwinters on the seed or on cabbage refuse.

CONTROL

Successful control measures have not been worked out. It is possible that seed disinfection will prove helpful. Where the disease is a transportation or storage-house problem, as in the case of cauliflower, control must be effected through a change in shipping or storage conditions. Humidity should be held as low as possible and the temperature maintained at 32° F. or slightly above.

POWDERY MILDEW

CHARACTERISTICS

Powdery mildew appears as a white powdery fungus growth in spots or as a more or less complete coverage on the upper surfaces of leaves and on stems of cruciferous plants. It occurs more abundantly in semiarid regions or in more humid areas after a protracted dry spell. The powdery material consists of the spores (conidia) and the branch of the mycelium on which they are borne. At a later stage, black bodies, smaller than a pinhead, appear embedded in the powdery mildew. They are fruiting bodies (perithecia) containing another type of spore (ascospore), and, being longer lived than conidia, protect the fungus against unfavorable environment.

CAUSAL ORGANISM

The causal fungus (*Erysiphe polygoni* DC.) attacks many plants, but is made up of numerous strains, one or more of which is probably confined to the crucifers.

CONTROL

Ordinarily the disease is of no economic importance on crucifers. Should remedial measures become necessary, finely divided sulphur applied as a dust gives adequate control.

DOWNY MILDEW

CHARACTERISTICS

Downy mildew differs from powdery mildew in that the causal fungus is conspicuous on the lower surfaces of leaves, where it forms a fluffy, downy growth, usually in well-defined areas. The effect upon the leaf tissue is such as to often cause yellow spots on the upper surface corresponding to the mildew growth beneath. The mildew is sometimes checked by dry weather, when the fungus growth becomes inconspicuous and the leaf spot may appear only on the lower surface of the leaf as a light area surrounded by a darker, often purple border. Stems and seed pods are also affected.

CAUSAL ORGANISM

The causal fungus (*Peronospora parasitica* (Pers.) DBy.) affects many cruciferous plants and is made up of many strains, each restricted to certain groups of host plants. The mycelium penetrates the plant through the breathing pores (stomata) and grows between the host cells, gaining its nutriment from knoblike projections (haustoria) into the cell itself. It produces spores by first sending out special branches on the surface of the lesion. These are what make up the mildew growth visible on the leaf surface. The thin-walled spores (conidia) are readily carried by air currents and are short-lived; but in relatively cool moisture they germinate promptly and produce fungus threads that enter the stomata to cause new infections. Within the tissue dark, heavy-walled resting spores (oospores) form. These can carry the fungus through long unfavorable periods.

CONTROL

The fungus thrives best in a cool, moist environment and is thus to be found chiefly in humid areas. If it becomes epidemic in the seedbed, spraying with bordeaux mixture should keep it in check. Damage to cabbage in the main field is not serious except in the winter Gulf coast crops. Here it attacks the outer leaves of the heads and predisposes them to secondary decays in transit, especially bacterial soft rot. The fungus mycelium persists in perennial roots and in storage organs such as cabbage heads and turnip roots. In both it causes a slow, dry decay in storage that occasionally becomes important. In such cases it may be diagnosed by placing decayed parts in a moist chamber, when the fungus ordinarily fruits readily on the surface.

WHITE RUST

CHARACTERISTICS

White rust occurs on many wild and cultivated crucifers and is world-wide in its distribution. The white blisterlike pustules on leaves and stems and seed pods break open to expose a white powdery mass consisting of spores of the causal fungus. These isolated pustules are seldom associated with any marked distortion of the plants. When the interior of young stems and flower parts are invaded, extensive malformation occurs, taking the form of excessive size and distortion. Flower petals, stamens, and ovaries grow to many times their normal size and can be recognized only by their relative position.

White rust is common on radish, but ordinarily not destructive except in midwinter greenhouse crops. Horseradish is perhaps more seriously affected than any crop in this country since when the perennial roots become infected the normal growth is impeded. The infection of seed plants causes occasional loss on radish in this country. White rust is not known on cabbage or cauliflower in this country, but it occurs on them in Europe, where it also causes occasional losses to the seed crop.

CAUSAL ORGANISM

The causal fungus (*Albugo candida* (Pers.) O. Kuntze) is closely related to the downy mildew organism. It also consists of several distinct strains each confined to certain hosts. Relatively short-lived spores (conidia or sporangia) are borne in the white pustules in chains on short branches of the mycelium. These conidia germinate best at a cool temperature; after a few hours in water, they each give rise to several swimming spores. The latter come to rest on the crucifer leaf and send out tiny threads which enter the breathing pores. The fungus mycelium then grows between the cells and feeds through haustoria, as the downy mildew fungus does. The spore-bearing branches form from the mycelium below the host epidermis, which is gradually raised as the pustule forms. The latter remains shiny and blisterlike as long as the host surface is unbroken and retains the spores intact, but it eventually breaks to release the conidia. The mycelium in young branches and in the flowers stimulates the host cells to multiply rapidly and abnormally, giving rise to malformations. In this tissue from the mycelium between the cells dark, thick-walled resting spores are formed (oospores), which serve to carry the fungus through unfavorable periods.

CABBAGE HEAD ROTS

CHARACTERISTICS

When cabbage is mature the head is made up of dormant tissue that becomes subject to diseases brought on by the attack of micro-organisms, many of which are of little danger to the growing plant. These are described elsewhere in this bulletin as head rots in connection with the following diseases: Black rot (p. 15); bacterial soft rot (p. 22); drop or watery soft rot (p. 24); rhizoctonia head rot (p. 21); black leaf spot (p. 25); and mosaic (internal necrosis) (p. 31).

In addition to these at least three other head rots may occur.

Pythium head rot.—This disease travels rapidly along the midrib, which is reduced to a soft, pulpy consistency but is held together by outer layers of tissue. Offensive odor is not characteristic, and the mycelium in the decaying tissue, unlike other head rot organisms, has practically no cross walls. The fungus (*Pythium debaryanum* Hesse) and its close relatives are common causes of soft decays of storage organs of fruits and vegetables and also cause rootlet decay and damping-off injury to many plants (p. 31).

Gray mold head rot.—This disease appears as a rather soft brown decay on the outer leaves of the heads. It is found usually after harvest in storage or transit, and is distinguished by the gray mold on the surface of the decayed tissue, which consists largely of the conidia of the fungus (*Botrytis cinerea* Pers.). Later, black sclerotia about the size of wheat kernels are formed not unlike those of the watery soft rot fungus.

Black mold head rot.—Another fungus often causing cabbage decay is the common bread mold fungus (*Rhizopus nigricans* Ehr.). It, like that of gray mold, is common on many fruits and vegetables in transit and market. It is distinguished by the long whiskery

threads on which are borne the black heads (somewhat smaller than the size of a pinhead), which are clusters of spores.

CONTROL

The bases of head rot control are: (1) Clean stock for storage or market; (2) careful handling to minimize injury; (3) storage at near-frost temperature and with adequate ventilation, and long-distance transit at temperatures low enough to retard decay but with protection from freezing.

FIGURE 12.—Upper surface of a cauliflower leaf, showing typical bacterial spot.

CAULIFLOWER BACTERIAL SPOT

Cauliflower bacterial spot occurs primarily on cauliflower, but it is occasionally found on cabbage. It occurs commonly on Long Island, in the tidewater district of Virginia, and the bay district of California; however, it has been observed in various other parts of this country and abroad. Small brownish to purplish-gray spots sometimes irregular in outline occur on both surfaces of the leaf (fig. 12). A puckering of the leaf results when the midrib and larger veins are infected abundantly.

This disease is due to a bacterium (*Bacterium maculicolum* (McCulloch)), and no means for its control have been worked out. It has been observed that the spot disease is most severe during cool, damp weather and is held in check when the warm, sunny days of late spring arrive. In view of the fact that the organism is especially sensitive to sunshine and warm weather, it is not likely to cause any serious damage except during protracted rainy, cool weather. Crop rotation should be employed in controlling it, and since the causal organism is probably seed borne the hot-water treatment of seed should be practiced.

BLACK ROOT OF RADISH

The white-icicle type of garden radish is very commonly affected with black root, a dark-brown to black dry decay of the fleshy roots, which makes them unsalable. This disease is caused by a fungus (*Aphanomyces raphani* Kendrick), which normally in-

habits the soil; the mycelium enters the fleshy root through the temporary wounds that are made when the small secondary roots push their way out. Once in the fleshy root, the fungus progresses through the tissue and kills cells, which soon discolor. The thick-walled resting spores of the organism are formed in the tissue.

In the icicle radish the secondary roots emerge in two opposite zones—on the taproot and approximately halfway up the fleshy root. In these zones black root occurs. In globe types of radish the fleshy part formed is almost entirely from the lower stem (hypocotyl), and secondary root zones do not occur except slightly at the base. As a result they are not noticeably affected. It is consequently necessary to avoid black root-infested soil for icicle type radishes. Other cruciferous crops do not appear to be affected.

MOSAIC

Mosaic results from the invasion of the plants by an infectious virus not visible under the most powerful microscope. Whether living or not, it increases rapidly within the host plant. Mosaic affects many of the cultivated crucifers, and it is sometimes destructive on turnip, rutabaga, cauliflower, and cabbage.

On the leaves a mottled effect occurs, resulting from lighter yellow and darker green areas than normal and so arranged as to give a mosaic pattern. This is most conspicuous on turnip, but on cabbage it is usually so mild that it is readily overlooked. The most serious injury of mosaic is the stunting effect it has on the plant as a whole. Another serious effect is that some of the tissue is killed and turns black or brown. These necrotic areas occur in affected horseradish roots, on cauliflower foliage, and on cabbage as spots on the outer leaves and often throughout the mature head (fig. 13). Mosaic-affected seed plants may be severely stunted.

The mosaic virus is carried from plant to plant by plant lice and is probably spread chiefly by this means. It may be transferred from diseased to healthy plants by injecting extracted sap from the former. The usual method of overwintering is in biennial or perennial plants, such as cabbage seed plants, horseradish, and cruciferous weeds. such as shepherds-purse and pennycress.

DAMPING-OFF

Damping-off of seedlings is common to many crops. It is associated with infection by a variety of fungi, and ordinarily the effects of individual species cannot be readily distinguished. Some fungi attack cruciferous and other plants only at the seedling stage and only under certain environmental conditions. In general, poor light and high moisture and other factors that promote the rapid extension of seedlings above ground rather than slow extension and more rapid thickening, bring on conditions conducive to damping-off. This effect has already been described in connection with rhizoctonia (p. 21).

Damping-off may be caused by the watery soft-rot fungus (p. 24), the blackleg fungus (p. 18), and by the same fungus which causes pythium head rot and its relatives. Control may be effected by

(1) using only soil of good texture, (2) the sterilizing of soil if it is used repeatedly, (3) rotation of outdoor seedbeds, (4) avoidance of too thick sowing, and (5) careful watering.

LEAF SPOTS

CHARACTERISTICS

Leaf-spot phases occur in a number of diseases already described. Chief among these are black leaf spot (p. 25); blackleg (p. 18); ring spot (p. 26); white rust (p. 28); downy mildew (p. 27); powdery mildew (p. 27); cauliflower bacterial spot (p. 30); and rhizoctonia disease (p. 21).

Other leaf-spot maladies on crucifers are described in the following paragraphs.

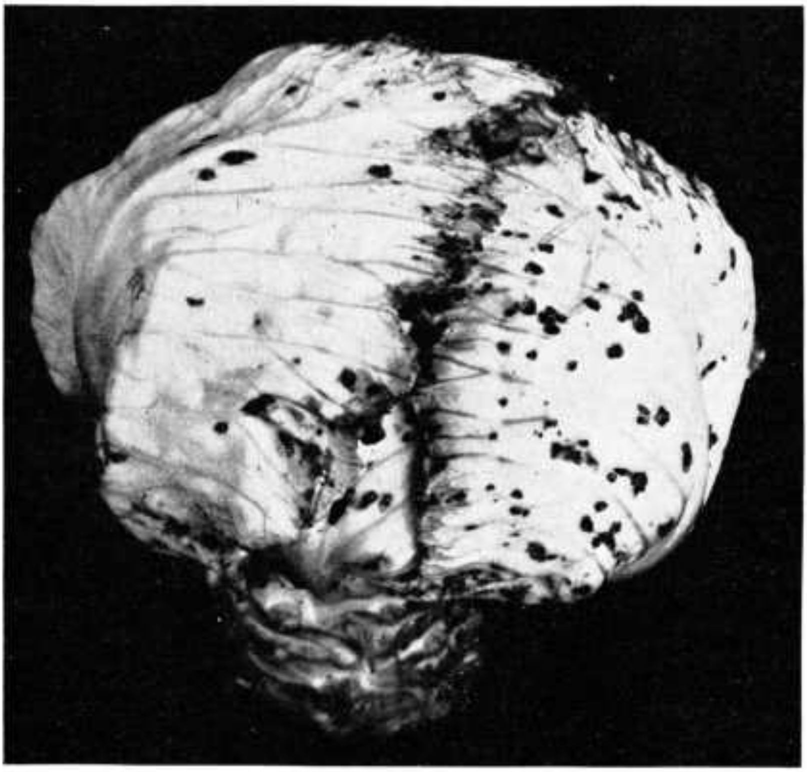

FIGURE 13.—Internal spot of cabbage heads associated with infection by the mosaic virus.

Anthracnose.—This is a common southern disease on turnip, Chinese cabbage, radish, and mustard; it consists of relatively small brown-bordered spots with grayish centers often coalescing. When heavy infection occurs, it may cause considerable damage to turnip and Chinese cabbage. In moist weather the fungus (*Colletotrichum higginsianum* Sacc.) fruits abundantly in the center of the lesions bearing short-lived conidia, which are dispersed chiefly by raindrops.

White spot.—White spot is another disease common in the South on the same hosts as anthracnose but usually of little importance. It is distinguished by white, bleached spots. If these spots become very numerous they destroy the marketability of turnip greens. The causal fungus (*Cercosporella albomaculans* (Ell. and Ev.) Sacc.) produces conidia on the surface of the leaf lesions.

Other leaf spots.—A number of other fungi, particularly *Cercospora* spp. and *Ramularia* spp., cause leaf spots on the minor cruciferous crops, such as mustard, horseradish, bunching turnips, and water cress. These are generally of minor importance and need not be discussed in detail here.

NONPARASITIC MALADIES

EFFECT OF LOW POTASH SUPPLY

Crucifers as a whole thrive best on soils that are practically neutral in reaction. Extreme acidity, such as prevails in some Atlantic-seaboard soils, results in abnormal growth, particularly if the soil solution is more acid than pH 5.0.

Cabbage is a heavy user of potash, and when its supply falls below a certain level, disease symptoms appear. These are characterized by the yellowing of the foliage between the veins and particularly around the margins of the outer leaves, where the tissue eventually dies and becomes brittle and saprophytic fungi develop. As plants in this condition pass into the heading stage the heads remain soft indefinitely, and as a result a marketable crop fails to develop.

This condition can be readily prevented by testing the soil before planting; there should be from 250 to 400 pounds of available potash per acre for a normal crop of cabbage. Even though effects of malnutrition fail to appear on the plants, a low-potash level results in cabbage of poor quality for sauerkraut manufacture.

MAGNESIUM DEFICIENCY

In many soils in eastern United States a low level of available magnesium results in characteristic disease symptoms on cruciferous crops. Yellowish areas develop in tissue between the veins of the leaves causing a chlorotic condition not unlike mosaic. As the disease advances the mottled areas may change to light-colored desiccated spots. The chief distinction from potash deficiency is that the latter causes chiefly marginal yellowing and dying. The yield of affected plants may be greatly reduced. The condition can ordinarily be corrected by the use of fertilizer which is made slightly basic with dolomitic limestone and to which small amounts of soluble magnesium salts have been added.

INTERNAL SPOT OF RUTABAGA, TURNIP, AND CAULIFLOWER

In northern Europe, Canada, and recently in this country, brown to black spots within rutabaga and turnip roots are a common trouble due to boron deficiency of the soil. They can be prevented by correcting this deficiency. Usually about 20 pounds of borax to the acre is sufficient. A similar trouble in cauliflower heads has been

noted in the Catskill Mountain area of New York, which is also corrected by addition of borax to the soil.

WHIPTAIL OF CAULIFLOWER

Cauliflower plants sometimes form abnormally narrow, ruffled leaves with irregular margins, and in extreme cases dwarfing results so as to preclude heading. This disease, known as whiptail, is primarily a malnutritional disorder and occurs chiefly along the Atlantic seaboard on highly acid soils. It may be corrected by the application of moderate amounts of dolomitic lime.

LOW-TEMPERATURE EFFECTS

Many crucifers grow well in cool climates and in fact do their best in such an environment. In the Southern States cabbage, cauliflower, turnip, and radish are favorite winter crops, since they harden well and withstand light frosts. Certain detrimental effects are to be recognized.

The bolting of cabbage to seed without coming to a mature head often occurs in the winter crop. This is brought about by protracted cool or frosty weather. Under such conditions cabbage goes through dormancy without heading. It is a purely environmental effect and cannot be attributed to poor seed stock, as is often claimed.

Multiple heading in the early northern cabbage crop from southern-grown cabbage plants sometimes causes appreciable losses. This is due to injury done to the main growing tip by frost when the plants are young. After transplanting, several side buds grow instead of the main growing point, and several small unmarketable heads result.

Freezing injury is most common on the late fall crop in the North. Freezing temperatures have various effects. Sometimes the more mature heads are most severely damaged; at other times immature plants suffer the most. The result depends upon which tissue has the highest freezing point. Variation extends to tissues in a given plant. Sometimes the interior leaves of a cabbage are injured and the exterior leaves are not harmed. Frozen storage tissue is predisposed to soft-rot bacteria, which rapidly destroy the weakened cells.

HIGH-SOIL-MOISTURE EFFECTS

The flooding of soil in cabbage fields is often the cause of the death of plants when the soil remains saturated for several days. Sudden permanent wilt occurs, and the root decays rapidly. This is not due to asphyxiation, as plants can be grown in liquid culture. It is more probably due to the abnormal anaerobic fermentation set up by the soil flora, which liberates substances in the soil solution that are toxic to the plants.

LIGHTNING INJURY

When lightning strikes the earth in cabbage fields plants soon wilt in roughly circular areas of various sizes. Within a few days most of the plants are dead. Such lightning spots are usually not

observed until some weeks after the occurrence, and there is thus commonly some question as to the cause. Certain characteristics help to distinguish it.

Around the margin of the area are to be found plants which are weakened or slowed up in growth. As these are pulled, it is usually found that the lightning scar is at the soil line and is limited to the side facing the center of the area. Sometimes this injury is slight and is rendered conspicuous by being callused over. Greater injury leads to a side stem growing out just below this point or to adventitious roots forming just above it. The electric charge apparently passes directly to the pith of the stem, in which it is conducted more readily. The lightning injures the pith most readily also, and some time after the injury the pith is hollow and dark-colored, and within it an abnormal development of fibrous roots occurs. The peculiar earmarks of lightning injury are very useful in diagnosing it several weeks later.

INTUMESCENCES

There often occur on leaves and stems of cabbage, cauliflower, and other cruciferous plants in the field, wartlike projections the size of a pinhead or larger, scattered in large numbers over either surface. These are the result of injury to the tissue brought about by the blowing of soil particles against the leaves. As a result of the wound, the tissue responds by building up callus, which takes this form. It is of no great importance, but owing to its very conspicuous nature it often attracts attention.

TRANSIT AND STORAGE DISEASES[2]

Various diseases that cause direct loss or necessitate heavy trimming of cabbage in storage are described briefly so that they can be recognized and avoided.

FREEZING INJURY

Heavy losses of cabbage occur annually as a result of freezing, both in the field (p. 34) and after harvest. Cabbage tissue has one of the highest freezing points (31° F.) found among vegetables. Sometimes frozen cabbage will thaw out without injury and sometimes it will not. In the former case the tissues are merely frozen, while in the latter they are frozen to death. However, there is no way of telling by examination of a frozen head of cabbage or of other vegetables which act similarly whether they will show injury and breakdown when they thaw out. Immediately after they are thawed, the frozen areas look water-soaked, because of suffusion with water liberated in the intercellular spaces by the thawing ice. If the cells are still alive, some of the water will go back into them; the only effect on the tissue is a slight wilting or shriveling due to the excessive loss of water by transpiration and evaporation. Tissues responding in this way become flabby, pithy, or spongy and tough and lose their characteristic flavor. Some of them can withstand the freezing proc-

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[2] Adapted by D. H. Rose, senior physiologist, Division of Fruit and Vegetable Crops and Diseases, from Miscellaneous Publication No. 292, Market Diseases of Fruits and Vegetables: Crucifers and Cucurbits. That publication may be purchased from the Superintendent of Documents, Washington 25, D.C., for 45 cents or consulted in libraries.

ess several times before the effect becomes pronounced; others show it immediately. If the cells are not alive, the water does not reenter them; it may be lost rapidly into the air, with attendant drying-out of the tissues; or it may remain and the tissues become a leaking, disorganized mass, which is attacked by saprophytic fungi and bacteria.

Whether ice formation in the tissues is attended by permanent injury and death seems to depend upon the degree to which the temperature falls, the rate at which it falls, the duration of the critical temperature, and the condition of the plant tissues themselves.

The presence of ice in cabbage tissues renders them rigid or brittle. Frozen leafy tissues and even such storage tissues as turnips and rutabagas lose their natural luster and take on a glassy appearance. Immediately upon thawing, they become water-soaked. The leafy green tissues in the water-soaked area also have a dirty- or muddy-green color. In colorless or fleshy parts there is at first no discoloration. Later the more sensitive tissues, especially the water-conducting tissues, may become yellowish brown and finally black.

In cabbage there is no such discoloration save possibly in parts of the stem. If the tissues have not been killed they soon lose the water-soaked appearance and look much as they did before, except that they may be more flabby. If the tissues are killed, discolorations usually develop; these discolorations vary with the different kinds of vegetables and tissues. The epidermis of tender, leafy tissues, such as cabbage, Italian broccoli, kale, and mustard, is often loosened in spots, especially along the petioles, midrib, and smaller veins; it appears blistered and can be removed easily. Fleshy tissues such as turnips, radishes, rutabagas, and horseradish often show no discolorations, except in the water-conducting tissues; these become yellow, brown, or black.

In cabbage the outer leaves seem to be more resistant to killing by freezing than the inner leaves and the stem. Generally they thaw out without injury. After prolonged exposure to freezing temperatures, the inner tissues, especially the pith of the stem, usually are killed; soon they become affected with bacterial soft rot.

In dry air the killed tissues may dry out. Leafy tissues usually become brittle and parchmentlike; more fleshy ones become spongy and pithy or hard and stony. In moist air various rots develop, depending upon the external conditions. Thin, leafy tissues usually are affected by bacterial soft rot, alternaria rot (black leaf spot, p. 25), or gray mold rot. More fleshy ones are attacked by bacterial soft rot, rhizopus rot, or other rots.

Control is obtained by preventing exposure of the products to critical cold temperatures for a long enough period to cause their death.

BACTERIAL SOFT ROT

The diseases grouped as bacterial soft rot are caused by bacteria of the *Erwinia carotovora* group. Soft rot probably causes more loss on the market than any other disease of cabbage and related crops. The reason is that practically all invasion of tissue by soft rot organisms is through wounds, the lesions of other diseases, or tissues weakened by mechanical agencies, freezing, asphyxiation, or aging. These

organisms will attack only injured or dead tissues, and such tissues only when they are wet. Breaks in the tissues or moistened surfaces provide the water and food the organisms need to get started and to carry on growth and reproduction.

The pith of stems or roots is very often affected; in cabbage the resultant condition is often referred to as "stump rot." Stump rot usually follows infection during cutting or after freezing. Unless care is taken in cutting to avoid heads affected by bacterial soft rot, it is easy to carry bacteria on the knife from diseased heads to the freshly cut stems; when moist, these stems provide ideal starting places for decay. In turnip and other root crops the lesions usually occur in the pith, starting at the crown of the plant. In cabbage the lesions usually are on the surface or in the pith, following bruises or wounds. If the lesions are on the surface, the outer decayed tissues can be removed and the progress of the disease arrested by drying the freshly exposed surface. If the stem is invaded or the disease penetrates deep into the head following black rot (p. 15), the entire head is worthless.

In transit and storage soft rot may be spread by contact, or by the oozing or dripping from the decayed tissues. There probably is much less actual spread of this decay in transit than of many fungus rots, because bacteria do not form mycelia, or fungus threads.

The soft rot organisms are particularly sensitive to drying and to direct sunlight. Wet, warm weather favors the rot.

RHIZOPUS SOFT ROT

Crucifers are often subject to infection by a fungus known as *Rhizopus*. This fungus is ever present in the air and soil, and consequently there is always more or less danger of infection if conditions are favorable. This disease is of little or no consequence in the field or on leafy crops such as mustard and kale; but on the more fleshy vegetables such as cabbage, cauliflower, turnips, and rutabagas consequent decay developing during transit and marketing sometimes causes considerable loss. The chief predisposing factors are wounds and high temperature. *Rhizopus* does not affect cabbage, cauliflower, or root crops in cold storage (32° F.).

In succulent tissues the decay is light brown, soft, and watery. In roots the rot is moderately soft and moist, but it lacks the characteristic disagreeable odor of the bacterial soft rot (p. 36) that sometimes presents a similar appearance. Usually in cabbages, cauliflower, brussels sprouts, and turnips the coarse, stringy fungus threads bearing white and black fruiting bodies make the diagnosis of this disease fairly easy.

GRAY MOLD ROT

In cabbage, cauliflower, and turnip, as in most other vegetables, gray mold rot (caused by a fungus known as *Botrytis*) occurs most commonly in aging tissues. Consequently it is of most importance in storage. There it is sometimes the most important single factor of loss, since the causal organism can grow at cold-storage temperature. The rot is found even in freshly harvested stock if conditions are especially favorable for the fungus. Chief among these is high humidity. If

this is associated with moderate temperature, the fungus attacks even the outer aging leaves of growing plants. Water-soaked, grayish-green areas are produced, and usually a gray mold is present on the surface of affected tissues. In the more advanced stages of decay the grayish-brown vegetative threads and spore clusters of the fungus are characteristic.

BLACK LEAF SPECK

Black leaf speck is characterized by small, sharply sunken, brown or black specks occurring anywhere on the leaves of cabbage, cauliflower, and Chinese cabbage, from all sections. At times these specks are found in great abundance, especially on the leaf blades. They may occur in a few of the outer head leaves only, or in leaves throughout the head. Frequently it is difficult to distinguish them from the early stages of black leaf spot (p. 25), which occurs in California cabbage, and from ring spot (p. 26) as it appears in Oregon cauliflower. The spots render these products unsightly, thus affecting their marketability. They also tend to lower their resistance to storage rots.

Very little is known about the factors that bring about black leaf speck, save that it is not caused by organisms. It occurs commonly in transit and storage; for this reason it might be classed as a break-down associated with low temperature. It also occurs sometimes in the field, where it has been found, in some instances at least, to have been definitely associated with a decided drop in temperature.

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